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RECENT ELASTOMERIC STRAIN TRANSDUCER DEVELOPMENTS*

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I. BACKGROUND

The development of the elastomeric strain gage has progressed through two stages and is well into the third stage.

The first stage consisted of conceptual evaluation. Small tubes (similar to macaroni in size), were cast from polyurethane and filled with an electrically conducting fluid (mercury); copper wire terminals were inserted into the tubes (and mercury) at the extreme ends and the ends potted to prevent the loss of the fluid. A near-linear electrical resistance change was noted as the conceptual configuration was elongated.

With the validation of the strain transducer concept, a second stage of effort was initiated in which a strain gage was designed, cast and tested*. The results of this work effort further demonstrated the practicality of the gage; however, certain undesirable gage features such as low nominal resistance and low sensitivity became apparent.

The third stage of development effort has been under way and has produced some noted improvements in the elastomeric gage. These are presented in the following discussion.

*DeHart, Rastrelli, Michie, "Techniques for Acquiring Subsurface Displacements in Viscoelastic Materials: Part B", Bulletin of the 4th Meeting, Working Group on Mechanical Behavior, Chemical Propulsion Information Agency, November 1965.

II. AREAS OF GAGE IMPROVEMENT

A. Capillary Diameter

An immediate approach to increasing the gage's nominal resistance was to decrease the sectional area of the gage capillary. In reducing the capillary's diameter from 6 to 1.7 mils, the nominal resistance of a 0.5-in. active element length increased from 0.4 to 8 ohms. A more significant change occurred in the gage's sensitivity increasing by a factor of 70; a comparison of the two capillary diameters is shown in the following table.

Capillary Diameter (mil)	Nominal Resistance (ohms)	Strain Sensitivity (ΔR/1% strain)
6.0	0.40	0.005
1.7	8.00	0.359

B. Gage Geometry

The reinforcing effects of foil and wire strain gages on metallic structures are normally negligible in magnitude and. consequently, ignored. However, for bodies composed of materials with low moduli of elasticity (e.g., elastomers), the strain gage reinforcing effects on the body's strain field become an important consideration. Further, whether an elastomeric transducer is to be surface mounted or embedded will, to a certain extent, dictate its configuration. For example, a surface-mounted gage should be supple while the stiffness of an embedded gage and the surrounding material should closely match.

To increase the suppleness* of the surface-mounted gage, the gage's sectional area of the Stage Two transducer configuration (Gage Models A and H) was reduced from 0.125 × 0.30 in. to 0.030 × 0.185 in.; a comparison of these gages is shown in Figure 1 and the following table:

Gage Model	Sectional Area (sq in.)	Suppleness* (gm/1% strain)
"A", "H"	0.0375	22.7
"B"	0.00555	3.52

Gage Model B is greatly improved over Models A or H with the stiffness (and hence the reinforcing effect) being reduced by a factor of 6.45.

C. Multiple Capillary

Another innovation to the elastomeric strain transducer is a design with multiple active elements (Fig. 2). The advantage of this scheme is the increase in nominal gage resistance and sensitivity. With this arrangement, a practical gage length can be reduced well below the present 0.5-in. A four-element gage is shown in Figure 3.

D. Casting Technique

In progressing to smaller diameter capillary gages (from 6 to 1.7 mils), a unique technique was devised to form the capillary and reservoirs in the gage body. A 1.7-mil nylon filament was suspended along the axis of a lathe and slowly rotated (Fig. 4). Small deposits of epoxy were applied along the nylon filament at predetermined locations. With the rotational motion, the epoxy deposits cured into near-perfect spheres; these spheres formed the reservoirs while the nylon filament formed the capillary.

*Suppleness is defined as the force required to elongate the gage through 1.0 percent strain.

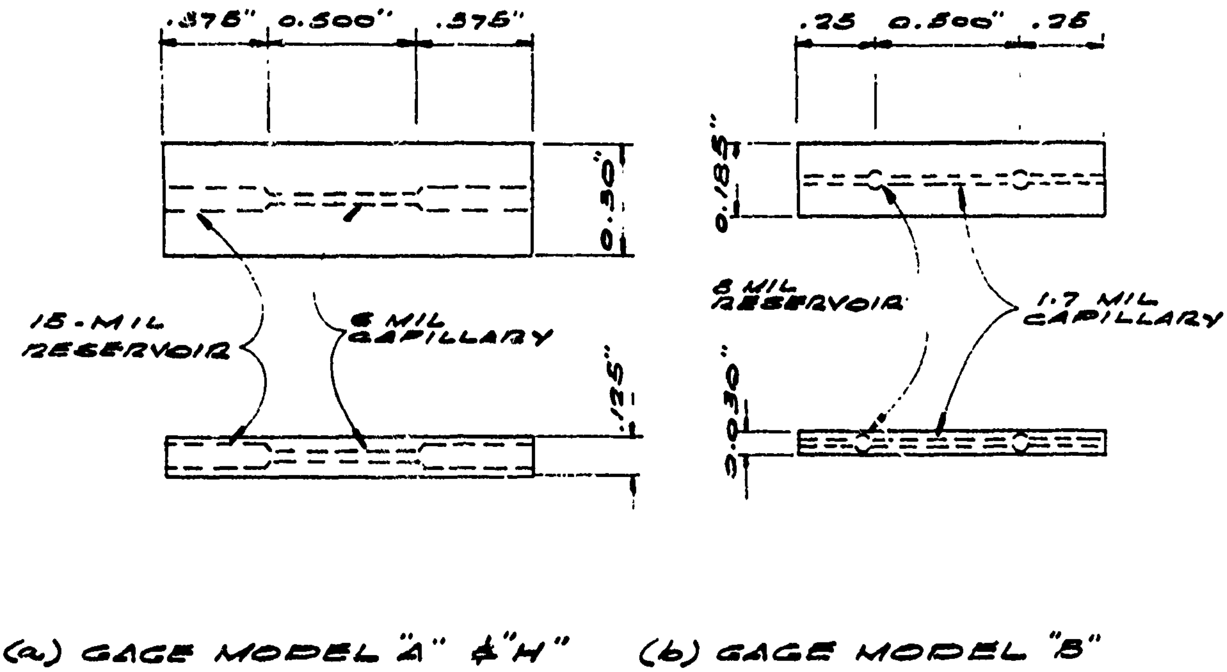

FIGURE 1 ELASTOMERIC STRAIN GAGE CONFIGURATIONS

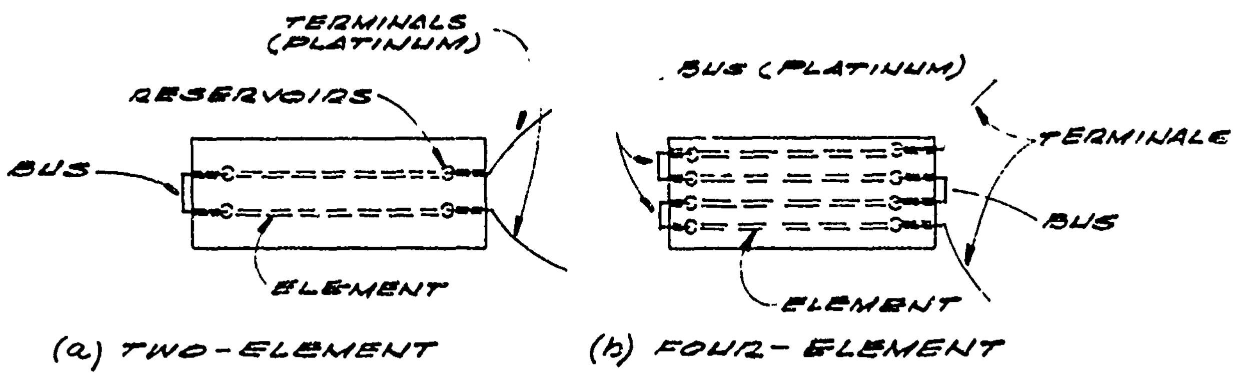

FIGURE 2 TYPICAL MULTIPLE-ELEMENT GAGES

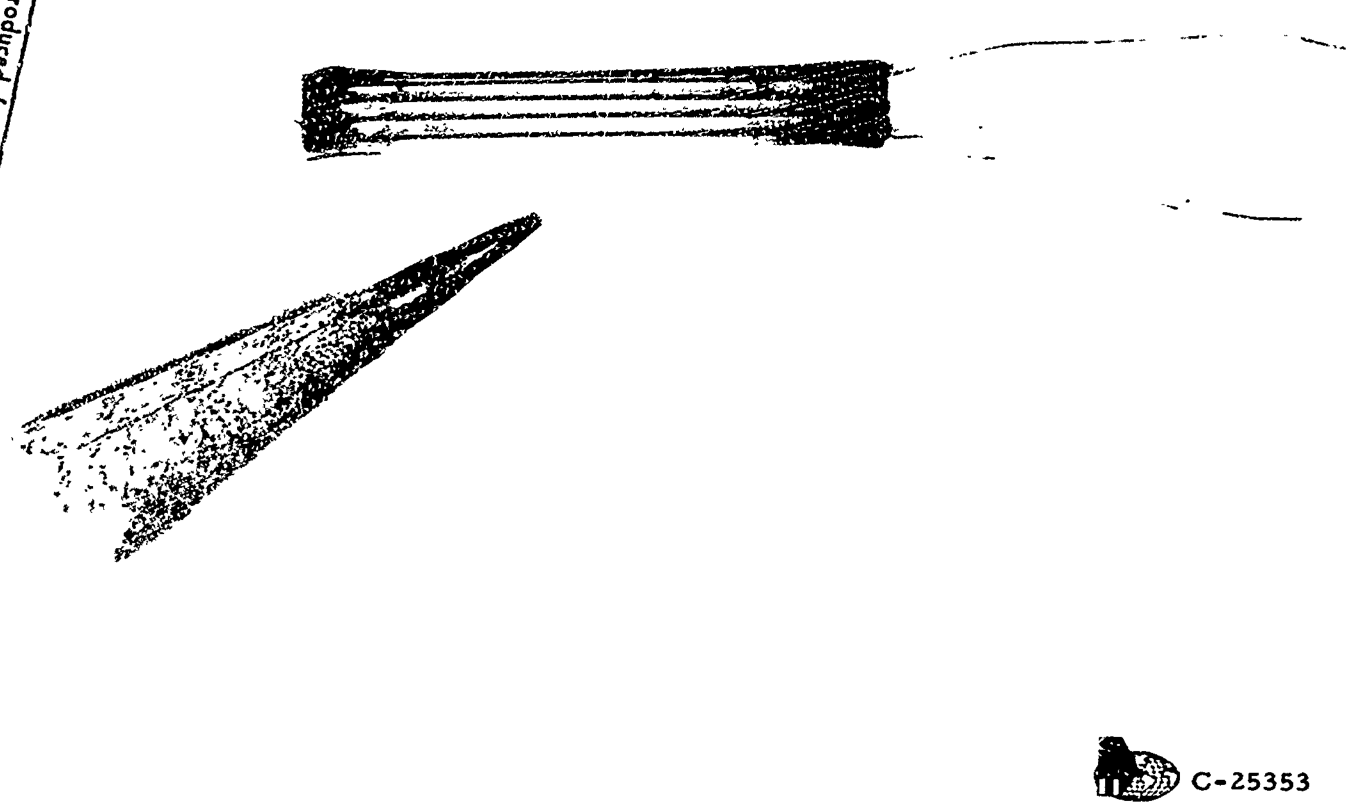

FIGURE 3 ELASTOMERIC STRAIN GAGE WITH FOUR ELEMENTS

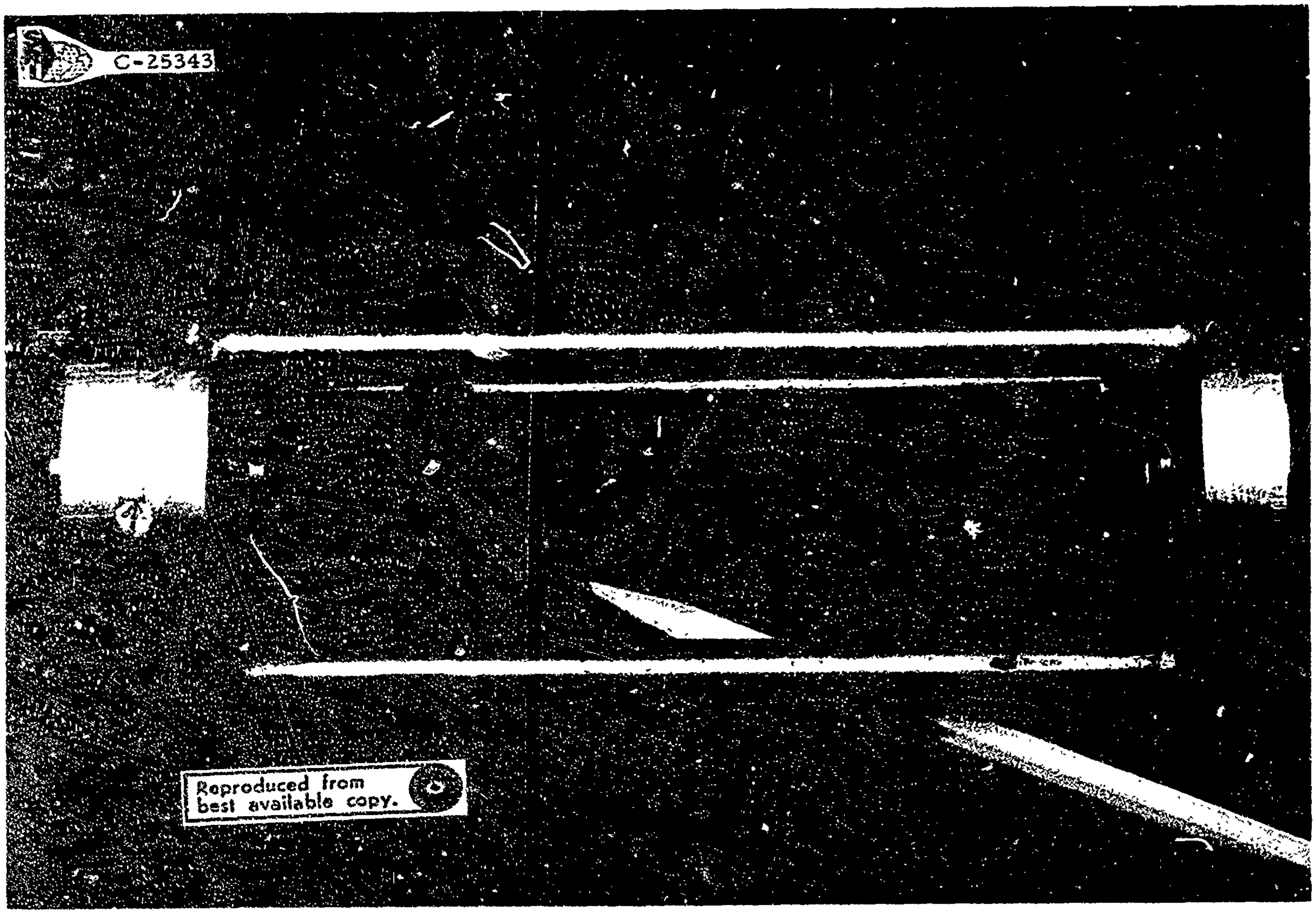

FIGURE 4 LATHE FIXTURE FOR APPLYING EPOXY SPHERES TO NYLON FILAMENT

The filament with the attached epoxy spheres was tensioned in the gage mold and the elastomeric compound cast. After the gage body had cured, the nylon filament and epoxy spheres were removed. In Figure 5a, the gage body is shown after a filament had been stripped; the body was trimmed (Fig. 5b) to a configuration containing a 0.5-in. long active element and two spherical reservoirs. Capillary and reservoirs were filled with an electrically conducting fluid (Fig. 5c), terminal leads inserted into the fluid (Fig. 5d), and gage ends sealed in a final elastomeric casting step (Fig. 5e).

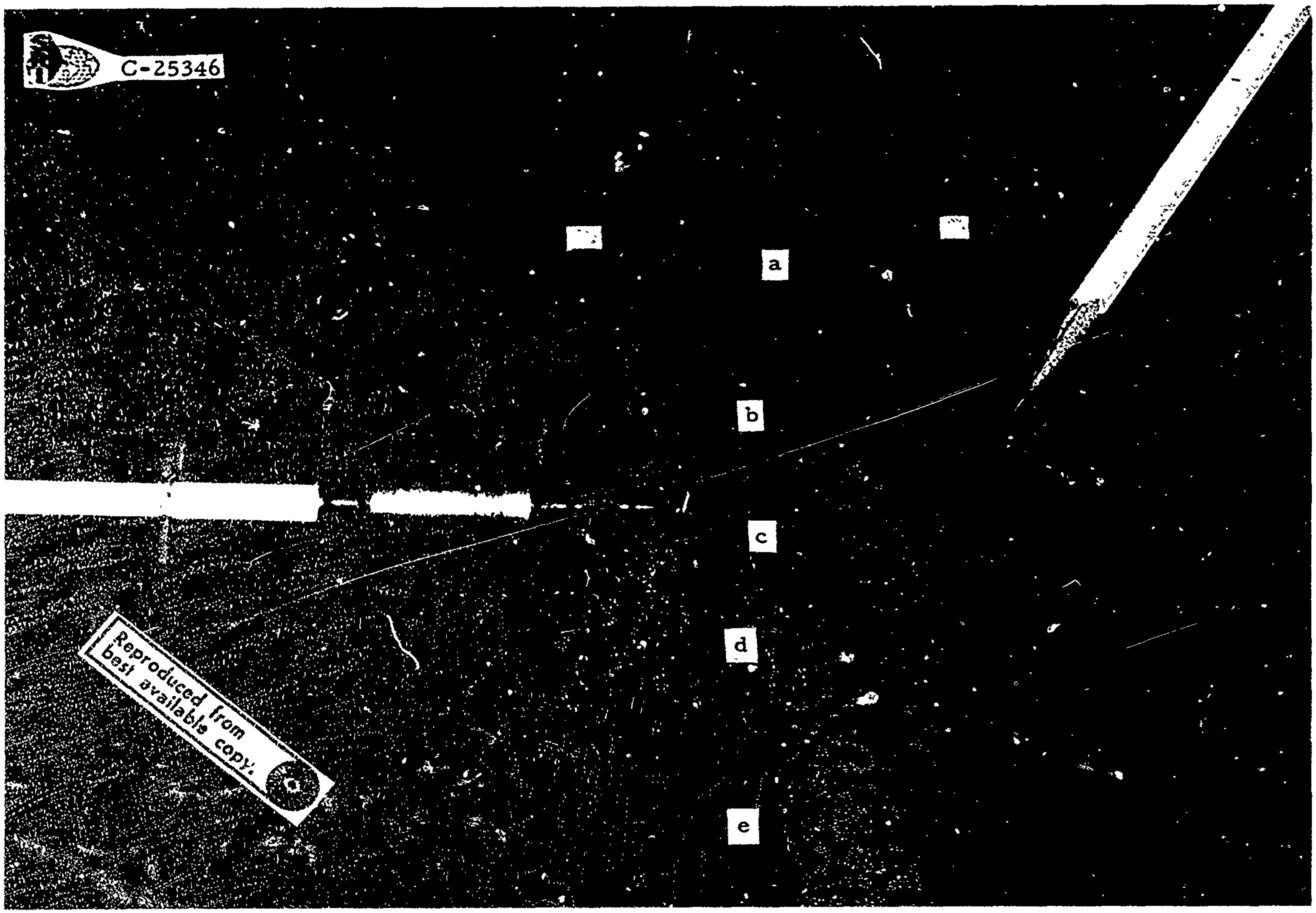

FIGURE 5 ELASTOMERIC STRAIN GAGE DURING VARIOUS FABRICATION STEPS